Notes and Discussion

THE CAMBALONG COMPLEX: A NEW METAMORPHIC COMPLEX IN SOUTHEASTERN N.S.W.

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A regional metamorphic complex has recently been mapped 12km west of Bombala in southeastern New South Wales. The complex is centred on Cambalong station (Fig. 1), and we have named it the Cambalong Complex. High grade metamorphic rocks have not previously been described from this area, although McRoberts (1948) mentioned two isolated occurrences of biotite-bearing metasediments to the west and southwest of Bombala and suggested that the metamorphic belt at Cooma could possibly extend south into this general region. This paper describes the field relationships of the complex and outlines its petrography and structure, as a basis for future more detailed studies.

Detailed mapping has revealed an elongate, north-south trending area of regional metamorphism, up to 7km wide and over 25km long. This is developed in a flysch sequence of probable Mid to Late Ordovician age (Bombala Beds). The metamorphic complex contains zones of progressively lower grade schists and phyllites on either side of a central belt of coarse-grained schists and gneisses. The central belt also contains foliated and unfoliated hornblende-bearing rocks and felsic dykes. Metamorphic zones are broadly concordant with the major structural trends in the area and the central belt lies in the core of an anticlinorium. The complex is asymmetric with zones on the western side being wider than equivalent zones in the east (Fig. 1). Much of the north-eastern end of the complex is covered by Cainozoic basalts and sediments.

The metamorphism of the complex probably occurred in the Silurian, by analogy with the Cooma Complex to the north.

The lowest grade rocks in the area are sandstones, slates and chloritic phyllites, with minor interbedded cherts and pyritic black slates. Bedding and other sedimentary structures are well preserved and at least three phases of folding can be recognized.

Fine-grained mica schists and interlayered quartzites mark the start of the main metamorphic complex. Metapelites in this zone consist dominantly of quartz, biotite, muscovite, minor albitic plagioclase and retrograde chlorite. They generally show a domainal schistosity defined by aligned mica aggregates which anastomose around recrystallized quartz and plagioclase grains.

Further into the complex, particularly on the western side, there is a well-developed zone of knotted mica schists. Rocks here include medium to coarse, foliated assemblages of quartz-biotite-muscovite and quartz-muscovite-chlorite with a variety of knot types including mica-rich aggregates, small porphyroblasts of partly retrogressed cordierite and large altered idioblasts of andalusite. Porphyroblasts generally predate the mica foliation and have retrogressed during or after foliation development.

Metasedimentary rocks in the central belt are mainly coarse-grained mica schists with a wavy foliation, and finely-banded quartz-mica gneisses. Locally there are some more massive micaceous quartzites and unfoliated metapelites with a coarse decussate texture. The central belt metasediments contain quartz, biotite, and muscovite with

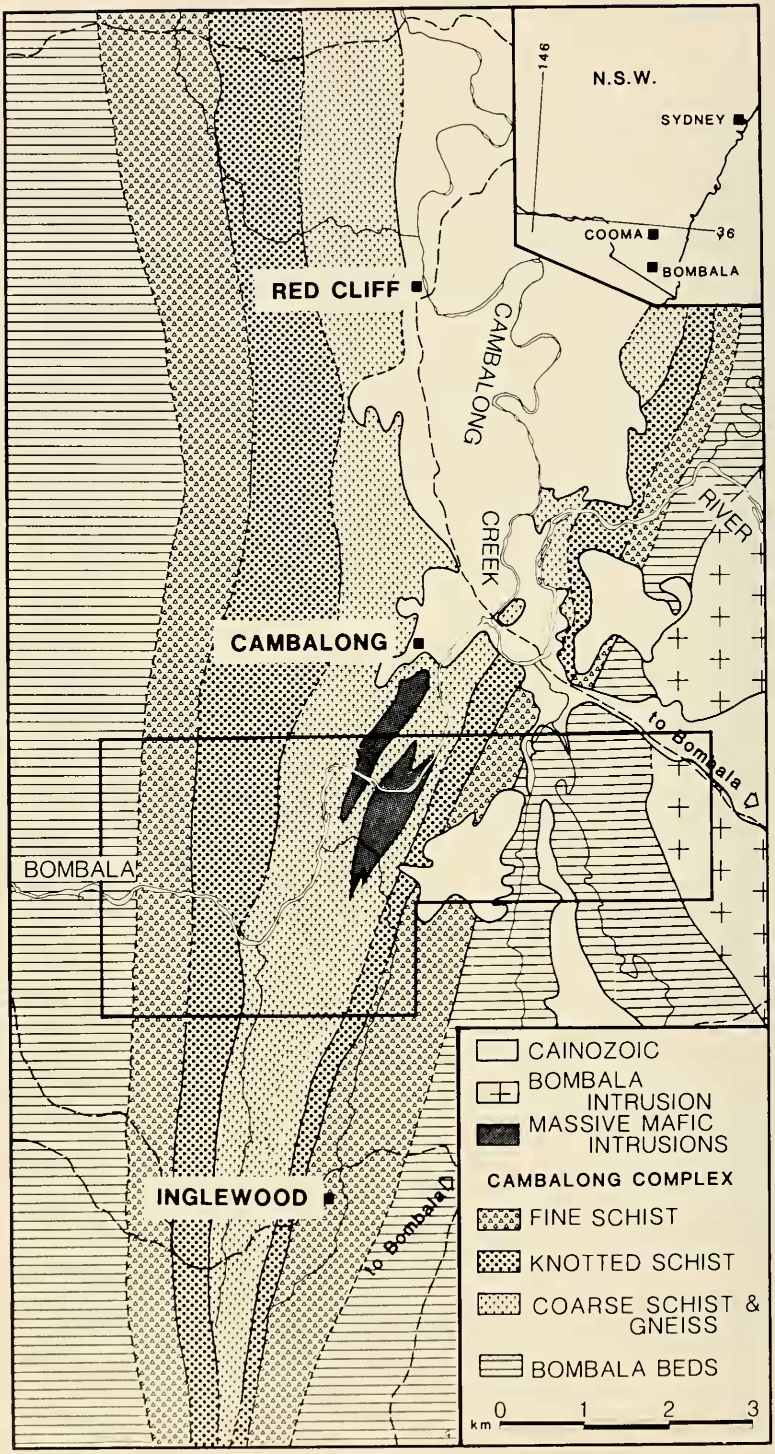

Fig. 1. General geology and location of the Cambalong Complex, west of Bombala. Outlined area is shown in more detail in Fig. 2.

variable amounts of plagioclase, andalusite, and cordierite. Some of the biotite has retrogressed to chlorite, and cordierite is replaced by fine-grained micas and amorphous material with low relief. Only a few acicular grains of sillimanite, enclosed in muscovite in one thin section have been identified. Aplite and pegmatite veins and dykes of centimetre and larger widths intrude the central belt metasediments. Where the metasediments are foliated, the foliation continues through these dykes and veins. It is unlikely that the numerous aplite and pegmatite veins could have been intruded if the metasediments had been at a temperature much lower than the solidification temperature of these felsic melts, i.e. at temperatures corresponding to high grade amphibolite facies metamorphism. This is also consistent with the mineral assemblages in the more mafic gneisses which have a close spatial association with the metasediments of the central belt.

Various foliated rocks, apparently derived from igneous precursors, and elongate bodies of massive tonalite, diorite and hornblendite are interlayered with, or intrude, the central belt metasediments (Fig. 2). The foliated rocks include hornblende-bearing types of acid to basic composition and more felsic rocks. The hornblende-bearing rocks contain granulated plagioclase, hornblende, biotite, quartz and epidote. The plagioclase (An_{40-60}) shows normal and oscillatory zoning. The rocks typically show a coarse gneissic banding of darker and paler layers and elongate lenticles. This banding is steeply dipping and parallel to foliation in surrounding metasediments. The paler bands and lenses are of tonalitic composition and are coarser and less granulated than the darker bands and lenticles of more mafic (gabbroic) composition. In some areas foliated hornblende-bearing rocks can be seen veining surrounding metasediments parallel to layering. They also contain metasediment rafts. Foliated felsic rocks consist of microcline, quartz, zoned oligoclase, biotite and muscovite, with accessory tourmaline, apatite and zircon. They have a granulated fabric with a foliation defined by anastomosing mica-rich bands. These rocks occur both as large mappable bodies elongate parallel to the regional foliation trends and as the aplite and pegmatite dykes and veins described above.

The presence of andalusite and cordierite and the absence of dense phases such as kyanite, staurolite, and garnet in the complex together with the narrow metamorphic zones, suggest a high geothermal gradient when the complex was forming. High geothermal gradients are typical of other early Palaeozoic metamorphic complexes in the southeastern highlands of Australia, such as the Cooma Complex, 75 kilometres to the north (Joplin, 1942; Hopwood, 1976), metamorphics at Jerangle (Hayden, 1980), and the Wagga Metamorphic Belt (Vallance, 1953). Detailed comparisons of pressure/temperature relationships in the Cambalong Complex with these other occurrences must await more detailed and careful sampling and petrographic studies on the Cambalong rocks. The apparent paucity of sillimanite at Cambalong, even in aluminous metapelites which are intimately veined with felsic igneous rocks, is something of an enigma. Original sillimanite may have been destroyed by retrograde metamorphism, which has affected most of the rocks thus far examined in thin section. Alternatively the rocks of the central belt at Cambalong may have been metamorphosed at temperatures not quite as high as those of high grade zones at Cooma and the Wagga Belt where sillimanite is more abundant.

The significance of the igneous rocks and metamorphosed igneous rocks in the complex is uncertain. The felsic rocks clearly intrude the metasediments. Aplite and pegmatite veins and perhaps also the larger dykes could represent products of partial melting of the metasediments. However, unlike the anatectic granite at Cooma (Flood and Vernon, 1978), they are relatively free of xenoliths and do not apparently contain cordierite or Al-silicates. The more mafic hornblende-bearing rocks could be

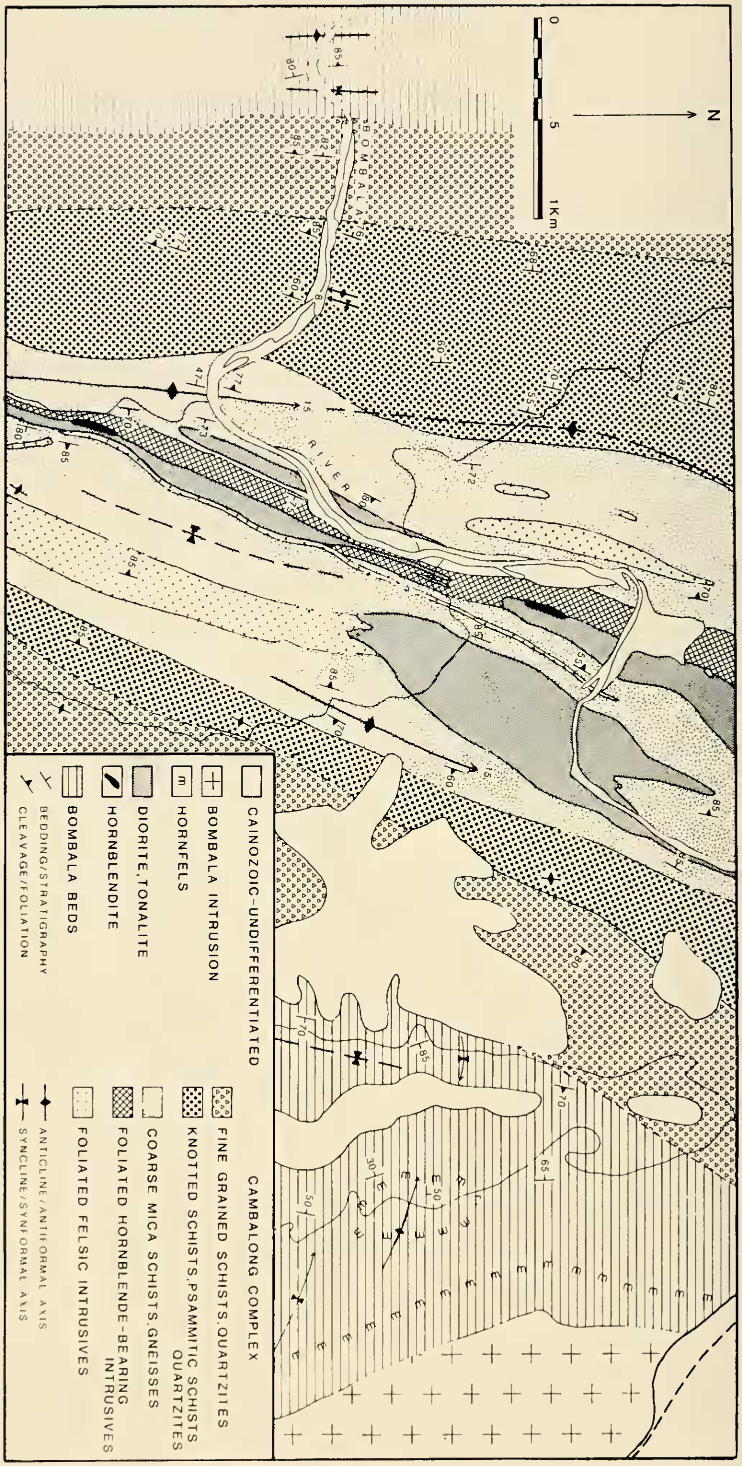

Fig. 2. Detailed geology of part of the Cambalong Complex. For locality refer to Fig. 1.

interpreted as synkinematic intrusives, emplaced during and/or soon after the main metamorphic episode, perhaps derived from more extensive areas of underlying mafic magmas. This could in turn account for the high geothermal gradient (cf. Miyashiro, 1982). They could also be interpreted as a pre-metamorphic complex of volcanics and associated intrusives at or near the base of the metasedimentary sequence. This latter interpretation would imply that the massive diorite and hornblendite bodies have largely escaped the imprint of later metamorphic events.

In the Cooma Complex, an S-type anatectic granite with associated migmatites is the major igneous component of the high grade core. More mafic hornblende-rich rocks are a very minor component, restricted to a few outcrops of amphibolite less than $1000m^2$, and xenoliths of hornblende-pyroxene granulite in the anatectic granite. Joplin (1942) interprets these as metamorphosed small gabbroic intrusives with perhaps some associated mafic volcanics, emplaced before the main metamorphic event. Hornblende-bearing xenoliths in the biotite-rich Murrumbucka Tonalite, north of the main Cooma Complex were interpreted by Snelling (1960) as being derived from the same suite of mafic rocks.

Tectonic features in the complex are best understood in the western low-grade and knotted schist zones. Here beds dip steeply west and are mostly west facing with some overturning. Structures include large sub-horizontal, steeply-inclined folds with a well-developed axial plane cleavage, steeply-plunging mesoscopic folds which affect both bedding and cleavage, and microscopic to mescopic kink folds with associated crenulation cleavage. Structures appear more complex in the central belt. Bedding and stratigraphic layering are preserved in some areas, but the dominant surface is a steeply-dipping metamorphic foliation. This shows isoclinal folding and locally contains a mineral lineation. Folded differentiated layering and a later axial plane fracture cleavage are common in some of the gneisses. Relationships between deformation and metamorphism in these higher grade rocks are currently being investigated. To the east, the complex grades rapidly into low-grade rocks which show more moderate west dips, much less penetrative deformation and some cross folding. These rocks have been intruded by largely undeformed, high-level plutons with well-developed contact metamorphic aureoles (Fig. 2). The structural relationship between these more gently dipping rocks and the metamorphic complex is not yet clear.

The Cambalong Complex is significant in that it is a regional metamorphic complex of considerable size whose possible existence was only hinted at in earlier publications and which is not shown on published regional maps. Its high-grade central core includes large areas of hornblende-bearing rocks of tonalitic, dioritic, and more mafic compositions — rock types which are poorly represented in the better known Cooma Complex to the north.

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